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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Technical Memorandum 33-505

Development and Testing of the Television Instrument for the Mariner Mars 1971 Spacecraft

JET PROPULSION LABORATORY
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PREFACE

The work described in this report was performed by the technical divisions of the Jet Propulsion Laboratory, under the cognizance of the Mariner Mars 1971 Project.

ACKNOWLEDGMENT

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ABSTRACT

This report describes the Mariner Mars 1971 Television Instrument. It emphasizes those aspects that are different from the Mariner Mars 1969 television subsystem. The various modes of operation are described and functional descriptions of the major elements in the system summarized. An electronic description of the circuits that differ from those of Mariner Mars 1969 is also presented along with a brief description of the calibration and test sequences.

I. INTRODUCTION

The Mariner Mars 1971 Television Instrument shown in Fig. 1 was designed to meet the requirements of the imaging experiment on the Mariner spacecraft. Generally, these requirements are:

(1) To map 70% of Mars at medium resolution and make detailed studies of 5% of the surface at high resolution.

(2) To obtain additional information on specific areas of interest, such as seasonal changes, polar caps and cap edges, nightside atmospheric and surface fluorescence, atmospheric haze, and cloud movements.

(3) To investigate and record various surface features such as surface slopes, elevation, brightness, and albedo differences.

(4) To obtain additional and refined spectral and photometric information about the planet and its atmosphere.

The contents of this report provide an overall description of the television instrument. Section II presents a discussion of the various modes of television operation followed by a functional description (Section III) which leads the reader through the system in the logical sequence of picture information flow. The functional description includes a discussion of the optics, the filter wheel, shutters, and sensors. Section IV describes the television electronics followed by subsystem calibration testing (Section V), and concludes with a description of miscellaneous functions (Section VI). The report places particular emphasis on components redesigned from the Mariner Mars 1969 imaging experiment (see Ref. 1). The general performance characteristics of the instrument are summarized in Table 1.

A discussion of the television interfaces is provided in the Television Functional Requirement (M'71-4-2036). A detailed electronic description is contained in the Television Operation and Maintenance Manual

(Electro-Optical System Document, Number 4028-001, Revised May 30, 1970). A description of the bench checkout equipment (BCE) developed for use with the television is contained in the BCE Operation and Maintenance Manual (Electro-Optical Systems Document, Number 4028M/BCE). The Television Performance Specification describes the typical performance achieved by the instruments. For a complete description of the optics used in the Mariner experiment, excluding changes specified in this report, refer to Ref. 2.

II. MODES OF OPERATION

The Mariner Mars 1971 Television Instrument employs two slow scan cameras to provide both wide-angle (camera A) and narrow-angle (camera B) photographic coverage of the planet. In conjunction with the data automation subsystem (DAS) and the Central Computer and Sequencer (CC&S), their capabilities include contiguous coverage of areas of the planet through recorded pictures with alternating A and B frames, A-only or B-only pictures, or A/B pairs in a non-contiguous mode on 84-s centers. The capability of in-flight operational checks accomplished by commanding a "calibrate" pair or a "dark current" pair also exists. Either fixed or automatic modes of operation for both the filter wheel and exposure control are available.

A. TV Picture-Taking Modes

Four basic picture-taking modes are used by the TV subsystem: dark current pair, TV calibrate pair, picture pair, and TV mapping. The dark current pair is a recording of a single A frame and a single B frame in which the camera is not shuttered. It is used to measure the "dark" signal output level of the vidicon.

The TV calibrate pair is used to check the electronic gain of the TV subsystem (TVS). Upon command, a known signal level is inserted in parallel with the vidicon target signal which produces a predetermined change in the video output level. This output can be recorded for comparison with previous data.

Picture pair is the mode in which a single picture is recorded from each camera. This sequence consists of an initial false shutter pair to determine the correct exposure level. It is followed by the recorded picture pair.

TV mapping provides continuous alternate picture taking by both cameras. The TV mapping sequence consists of a false shutter pair followed by 63 continuous pictures. A full tape load of 32 pictures may be recorded. At the end of 63 pictures, the TV is automatically reset to the ready or non-shuttering mode. It is necessary to use 63 pictures in this mode to make the logic compatable with A-only or B-only picture modes, where a total of 63 pictures are shuttered but only 32 are recorded.

B. Exposure Control

The exposure control for each camera is totally independent. Both fixed and automatic control modes exist. Each camera may, independently, be placed in either mode. Both cameras have the capability of 12 discrete exposure times which range from 3 ms and increase by a factor of two to 6.144 s.

In the fixed mode, the exposure time is selected by a coded command sent to the flight command subsystem (FCS). The DAS receives this command from the FCS and generates a set of pulses that correspond to the commanded exposure time. At the proper time, they are sent to the TVS to shutter the camera.

In the algorithm mode, each camera, in conjunction with the DAS, is capable of automatically incrementing the exposure higher or lower over a limited three-exposure range to compensate for the changing brightness of the Martian surface. In this mode, the next exposure time is based on the previous video level which is represented by the "pixel average" from the vidicon readout. At the beginning of a picture-taking sequence, the cameras are initially shuttered at 96 ms for camera A and 12 ms for camera B (called false shutter pair). Based on the value of the pixel average, the exposure time is increased to the next higher value, is left the same, or is decreased to the next lower value. The pixel average consists of the four most significant bits of the summation of 49 pixels in each of 88 selected lines in the top half of the picture. Figure 2 lists the exposure times for each camera in the algorithm mode and shows how they change with different values of the 4-bit pixel average. It should be noted that all of the above processing takes place in the DAS.

An inequity exists with the camera A exposure control when the filter wheel is stepping in the automatic mode. Due to the fact that the exposure setting is determined through a filter element which has since stepped out of the field of view, it is possible that a variation in picture brightness between filter elements during an exposure sequence may occur. This is due to the differences in individual filter transmissions, the coloring of Mars, and the varying optical and vidicon responses over the spectral range.

C. Filter Wheel Operation

The filter wheel is capable of two modes of operation, automatic or fixed. In the automatic mode, the filter wheel steps through the interference filters at positions 2, 4, 6, and 8. In the fixed mode, any of the eight filters may be selected by advancing to the desired positions at a maximum rate of two steps per 84 s. The solenoid-operated filter wheel rotates in one direction only.

D. Beam Blanking

Beam blanking is a condition in which the electron beam in the vidicon is turned off when the TV system is on. This prevents unnecessary scanning of the vidicon target when picture taking is not desired, thus extending target lifetime. Beam blanking can also be used to produce dark current build-up pictures and multiple-exposure pictures for star imaging. A coded command or a direct command is sent when beam blanking is desired.

E. Pause Mode

The pause mode prohibits the start of a picture taking sequence by delaying the start of frame A. This delays the remaining pictures and effectively changes the time at which the cameras shutter with respect to a fixed reference time.

III. FUNCTIONAL DESCRIPTION

Major differences between the Mariner Mars 1971 TVS and the Mariner Mars 1969 TVS are listed below. Each item will be described in this report.

(1) Optics A aperture.

(2) Camera A filter wheel.

(3) Camera A shutter.

(4) Single shutter direction.

(5) New signal chain.

(6) Addition of a carrier frequency generator.

A. Optics

The optics used in the Mariner Mars 1971 television experiment are essentially the same as those used for Mariner Mars 1969, the only difference being the change in relative aperture of optics A from f/5.5 to f/4.0 and a minor change in structure in optics B secondary mirror holder.

The wide-angle camera A uses a modified Ziess 50-mm refractive lens system providing a field of view of 11 × 14 deg. Located behind the lens is an eight-position filter wheel containing four interference filters in positions 2, 4, 6, and 8, polarizing filters in positions 3, 5, and 7, and a Schott GG495 minus blue filter in position 1. The spectral response of each is shown in Fig. 3.

Camera A employs a transparent cover located in front of the lens to protect optics A from contamination during flight. The cover consists of a quartz window and opening mechanism. A solenoid latch keeps the cover in place over the optics. After the cover deploy command is sent, the cover swings away and cannot be reset. The cover solenoid can be activated either by the FCS or the CC&S.

The narrow-angle camera B optics consists of a 500-mm catadioptric telescope with an effective aperture of f/2.35 and a field of view of 1.1 × 1.4 deg. A single fixed Schott GG495 minus blue filter is present in Camera B.

B. Filter Wheel

The filter wheel in camera A contains eight filter positions, each having a spacing of 22.5 deg. The filter wheel logic circuits receive advance pulses from the DAS. These pulses arrive during the time that camera A is in the erase mode. The filter wheel is advanced by a capacitive discharge into the filter wheel solenoid coils. The capacitor banks are time-shared with the shutters. The filter wheel is advanced by one or two positions or is left stationary as determined by the input command signals.

The filter wheel position is determined by the photo detector circuit which consists of four photo transistors positioned opposite to four light-emitting diodes. Interposed between the light-emitting diodes and the photo transistors is the filter wheel which contains a set of coded holes for each position.

The filter ID write circuit receives this binary-coded four-bit parallel-input signal from the filter wheel photo detectors. The light-emitting diodes are turned on for a period of 76 μs shortly after the filter wheel advances. The read strobe arrives during the last 8 μs of this period. The read signal allows the write circuit to send its outputs to the DAS and the science operational support equipment. The DAS uses these signals to determine if the filter wheel is in the right position and inserts position information into the telemetry data.

C. Shutters

The shutters for cameras A and B are identical two-blade focal plane shutters, each powered by its own permanent magnet rotary solenoid. The solenoid coils have bifilar windings which enable the direction of the shutter blades to be reversed by switching the current from one half of the winding to the other half.

The shutter logic circuit receives a shutter start/stop pulse, frame A pulse, and frame B pulse from the spacecraft DAS. In addition to the DAS signals, the shutter logic circuit uses the power supply +4-V output as an input signal. The shutter logic circuit processes the input signals to supply signals to the shutter drive circuits. Input signals are processed to sequentially reset the shutter blades, then operate shutter blades to give the desired exposure. The shutters are activated by discharging capacitor banks

into the shutter solenoid coils. If power is shut down or fails during an exposure, a safety device closes the shutter to prevent damage to the vidicon.

D. Sensor

A GEC (General Electrodynamics Corp.) imaging tube is employed in both cameras; the imaging tube is a 1-in. slow scan vidicon with electromagnetic focus and scan. A long persistence selenium sulphide photoconductor is used to allow storage of images for the 42-s read time of the camera. Each 42-s frame consists of 700 lines with 832 picture elements per line, producing a total of 582,400 picture elements in a single picture.

IV. ELECTRONICS DESCRIPTION

The TVS is electronically divided into six major sections:

(1) Signal chain.

(2) Sweep circuits.

(3) Vidicon support.

(4) Power supply.

(5) Engineering telemetry and science operational support equipment (SOSE) data.

(6) Grounding.

With the exception of the data processor and the power supply functions, the two camera chains are independent.

A. Signal Chain

Both the signal chain and data processor were completely changed from the Mariner Mars 1969 version. The signal chain consists of a preamplifier, a post amplifier, two band-pass filters, an isolation amplifier, a synchronous demodulator, a low-pass filter, a base band video amplifier, and an analog-to-digital (A/D) converter (see Fig. 4). The output signal of the vidicon is a 28.8-kHz amplitude-modulated carrier. The carrier is generated by a phase-lock loop that is synchronized to the spacecraft 2400-Hz power and is used to improve the noise characteristics of the instrument. The basic frequency of the loop is 460.8 kHz. This is divided by 16 to produce the 28.8-kHz carrier, which is the twelfth harmonic of 2400 Hz. This signal is used to control the cathode voltage and is phased so that the beam is off during the transitions of the 2400-Hz spacecraft power. This signal is also used as a reference signal for the synchronous demodulator.

The preamplifier is a transresistance amplifier that presents a virtual ground current summing node to the vidicon target. The signal gain of the amplifier is such that a 4-nA peak-to-peak input current results in an 80-mV peak-to-peak output voltage. The 3-dB bandwidth points of the preamplifier are 1 to 40 kHz. This is sufficiently wide to pass the 28.8-kHz carrier and its side bands.

Band-pass filter 1 is a second-order Butterworth filter with a center frequency of 28.8-kHz and provides a nominal gain of 27 dB to frequencies between 21.45 and 36.15 kHz. The signal-to-noise ratio of the carrier signal is improved by attenuation of all frequencies outside the 14.7-kHz bandwidth of the filter. It was installed in this location particularly to reduce nonlinear "spike" mixing.

The post amplifier is an operational amplifier with an adjustable gain of one to eight, which is used to compensate for variations in vidicons from camera to camera and to reduce phase distortion. The post amplifier gain is adjusted to supply a full-scale output signal of 5 V peak-to-peak. Video level clamping assures that the amplitude of the output signal does not exceed 5 V peak-to-peak.

The ac isolation amplifier is a differential amplifier located in the TV driver, and is used to reject noise induced in the camera head grounding system, or in the signal lines. The ac isolation amplifier output signal is referenced to the TV driver ground, and is used as an input signal to band-pass filter 2.

Band-pass filter 2 provides the same frequency pass band as band-pass filter 1. The nominal amplification factor for frequencies of 21.45 to 36.14-kHz is zero dB. The signal-to-noise ratio is improved as frequencies outside the pass band are again attenuated while the carrier and its side bands pass through virtually unchanged. The output of the band-pass filter goes to the ac video switch and to the synchronous demodulator.

The synchronous demodulator has a nominal gain of 6/5, which is adjustable over a limited range. The synchronous demodulator receives the chopped video signal from band-pass filter 2, and then full wave demodulates this signal with the 28.8-kHz signal which it receives from the carrier frequency generator. Synchronous demodulation further improves the noise rejection of the system.

The low-pass filter receives the base band video output from the synchronous demodulator and passes the signal to the dc isolation amplifier. Frequencies below 7 kHz are passed with essentially a gain of unity. The low-pass filter presents a 70-dB attenuation to the 28.8-kHz carrier frequency and eliminates it from the demodulated signal.

The dc isolation amplifier is a differential amplifier located in the data processor, and is used to reject noise induced in the TV driver grounding system or in the signal lines. The dc isolation amplifier supplies a nominal voltage gain of one to the base band video signal. Two outputs are supplied by the dc isolation amplifier. One output is connected to the dc video switch. The second output is connected to a test point.

The dc video switch receives base band video signals from cameras A and B. The video switch connects the active channel analog video signal to the 10-kHz video amplifier and the A/D converter. In this manner, the 10-kHz video amplifier and A/D converter alternately receive camera A or B analog video signals.

The analog-to-digital converter receives, in addition to the analog input signal, a continuous clock input of 176. 4 kHz (A/D converter bit sync), a 14. 7-kHz sample strobe, and a start conversion pulse from the DAS.

The A/D converter receives 12-bit sync pulses for each sample strobe. The sample strobe pulse causes the A/D converter to sample the video analog input voltage. The start conversion pulse is received 3 bit sync pulses after the sample pulse. The conversion pulse starts the 12-bit serial output signal, which is generated at the bit sync rate of 176. 4 kHz. After the 12 binary bits have been generated, a new sample pulse is received to stop the output and take a new sample.

The A/D converter output signal is a binary code representing the input voltage level present at the time of the sample strobe. The first bit generated is the most significant bit (MSB) and the last bit is the least significant bit (LSB). A full scale analog input voltage of 5. 99 V results in a binary output of 111111111 for a total decimal count value of 511. Processing in the data automation subsystem takes the 12 bits generated at 176. 4 kbps and buffers them by 9/12 to 132. 3 kbps, which is the rate at which video data is recorded on the tape recorder. The digitized video from the TV subsystem is formatted by the DAS and sent to the data storage subsystem (DSS) for recording.

B. Sweep Circuits

The active frame scan on one camera target requires 42 s and is composed of 700 lines per frame. Cameras A and B are actively scanned during alternate 42-s intervals. Immediately following an active scan, the camera

target is erased by 14 erase frames. Each erase frame requires 2.1 s. The frame sweep generator is gated to generate the read scan sweep and the erase sweeps.

The line sweep generator receives a signal composed of line-scan pulses combined with line-erase pulses. This signal has 700 line-scan pulses followed by 11,760 line-erase pulses. The period of a line-scan pulse is 60 ms; the line-erase pulse period is 2.5 ms. A second signal gates the line sweep generator in such a fashion as to cause it to produce 700 line sweeps for each frame or vertical sweep.

C. Vidicon Support Circuits

The vidicon support circuits are divided into the following functions:

(1) Cathode chopping.

(2) Target switch and calibrate.

(3) Focus and alignment.

(4) G1 voltage.

(5) High-voltage power supply.

The cathode beam chopping circuits inhibit the vidicon beam during the 3.4-ms retrace of each active scan line sweep, during the last 12.6 s of the erase cycle and during each frame retrace in the erase cycle. The vidicon conducts continuously throughout the active portion of the erase cycle to improve erasure, and is chopped with 50% duty cycle 28.8-kHz pulses from the carrier frequency generator during the 56.6-ms active line scans.

The target switching circuit increases the target voltage by 0.2 V during vidicon target erasing. This higher target voltage improves the erasing of the vidicon target.

The calibration circuit is used to produce a one-eighth full-scale video signal at the input to the preamplifier, thereby calibrating the entire signal chain.

The X and Z alignment coil current regulators are identical. The regulator circuit receives an unregulated 18 V from the power supply. The alignment current range is ±5 to ±50 mA. The X and Z alignment coils correct for shading effects.

The focus coil current regulator receives an unregulated +18 V from the power supply. The magnetic field of the focus coil focuses the vidicon electron beam on the vidicon target. A nominal 70 to 80 mA of focus coil current is required to focus the vidicon beam.

The G1 voltage divider obtains its voltage from a -100-V power supply. The resistors in the voltage divider are selected to provide the optimum bias voltage for the vidicon (G1).

The high-voltage power supplies are located in the camera heads and are powered by the ac regulators located in the power supply. The high-voltage power supplies produce 620 Vdc for G2 and 710 Vdc for G3.

D. Power Supply

The power supply receives input power from the spacecraft. The input power is a 50-V rms square wave at 2.4 kHz. The power supply converts the input power into the various voltages required by the TVS. Input power limiting is provided for spacecraft protection. Most power supply outputs are regulated and protected against short circuits.

A current limiter circuit regulates the input power drawn by the TV subsystem. The primary winding of the input transformer is in series with the ac power line and all other spacecraft subsystem power supply transformers. Therefore, all input power must pass through the primary windings of the input transformer. Input current limiting is obtained by varying the impedance of the input transformer to counteract any overload demand. The power supply is divided into the following units with associated parameters:

Power supply	Percent regulation	Current limiter
Current limiter	±10%	1 A
-100 V	±2%	22 mA
+50 V	Unregulated	None
+40 V	0.001%	22 mA
+15 V	0.1%	700 mA
-15 V	0.1%	700 mA
+6.3 V	0.01%	430 mA

Power supply	Percent regulation	Current limiter
+4.0 V	Unregulated	430 mA
AC regulator	2%	75 mA
Alignment	±2%	None
Focus	±0.001%	None

E. Engineering Telemetry and SOSE Data

The engineering telemetry circuit monitors a total of 15 test points which are reduced to 10 discernable data points. The commutator circuit selects a new test point every 4.2 s to complete 10 circuits for each camera frame time. The telemetry analog to pulse width (A/PW) output signal is connected to the DAS for further processing and transmission to the Flight Telemetry System and the DSS.

The 15 test points and 10 telemetered points which are monitored by the engineering telemetry are:

Camera A cathode current		(1)
Camera B cathode current		(2)
Camera B grid 2 voltage		(3)
Camera A grid 2 voltage		(4)
Frame A sweep Frame B sweep Line A sweep Line B sweep Cover A status	Ladder voltage	(5)
Power supply input current		(6)
Focus coil A current Focus coil B current	Differential focus	(7)

Optics B temperature	(8)
+4-V power supply	(9)
Average analog video	(10)

The science operational support equipment (SOSE) data signals are selected signals used to monitor various functions of the TVS during ground testing. The selected signals are the modulated carrier frequency, base band video, digital video, and carrier, all of which verify operation of the video chain. In addition, the A/PW commutator output voltage and filter position signals are available to provide checks on the engineering telemetry data and the location of the filter wheel.

F. Grounding

The grounding philosophy followed for the television subsystem is to divide all grounds into three grounding systems: signal ground, logic ground, and chassis ground. The common star approach is used in each grounding system with the data processor as the central ground point. The signal ground contains mainly signal chain circuits; logic ground contains mainly logic circuits and the vidicon sweep circuits. Chassis ground contains the chassis grounds for the television subsystem subchassis. By using a common star three-system ground approach, the effects of high currents or transients on one ground introducing noise on another ground are minimized.

V. CALIBRATION AND TEST SEQUENCE

Prior to and after delivery to JPL, the TV electronics and the optics are extensively tested on the component and subassembly levels. They are then mated and focused, and the electronic gain is set. After integration, an acceptance test is performed. Bench I calibration follows, and the TV subsystem is then sent through flight acceptance (FA) vibration testing. Next, the TVS is submitted to FA thermal/vacuum testing, during which it is calibrated at 20°C, 5°C, and -10°C. Environmental testing (subsystem level) is concluded with FA cold tests at -15°C and FA hot tests at 35°C. After FA testing, Bench II calibration is conducted. The instrument is then delivered to the Spacecraft Assembly Facility (SAF). It is mounted on the scan platform and eventually subjected to spacecraft environmental testing. System calibration verification is done at the SAF. Prior to shipment to the Air Force Eastern Test Range (AFETR), it is removed from the spacecraft and a third bench calibration (Bench III) is conducted. A final calibration verification is performed prior to launch at the AFETR.

VI. MISCELLANEOUS FUNCTIONS

The power-on logic, power-off logic, vidicon temperature control, and optics B temperature control circuits are grouped under miscellaneous functions. The power-on logic circuit provides a delayed gating signal. The delayed signal resets selected flip-flops and inhibits logic circuits effected by stored power supplies. The first frame pulse following the minimum delay sets the power-on signal to remove the inhibit and reset signal.

The power-off logic circuit draws power from a stored power supply. At power turn-off, the power-off signal goes high and remains high until the storage capacitor discharges. The power-off signal triggers the shutter logic circuits to assure that the camera shutters are closed when power is removed.

Both camera heads contain identical resistive heater networks. The camera head heaters maintain the cameras at operating temperature while the TVS is off to minimize the effects of warm-up and drift. The camera head heaters operate during the spacecraft cruise mode and are turned off during camera operation. To provide assurance that the temperature gradient along optics B does not exceed 7°C, a heater which operates continuously is located on the optics barrel. The heaters draw unregulated power directly from the solar panel supply. The vidicon heaters are externally controlled by the power subsystem.

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2. Montgomery, D. R., and Adams, L. A., "Optics and the Mariner Imaging Instrument," Appl. Opt., Vol. 9, pp. 277-287, Feb. 1970.

Table 1. TVS specifications

Parameters	Camera A	Camera B
Effective focal length	50 mm	500 mm
Focal ratio	f/4.0	f/2.35
Fastest exposure time (approx)	3 ms	3 ms
Angular field of view	11 × 14 deg	1.1 × 1.4 deg
Active target raster	9.6 × 12.5 mm	9.6 × 12.5 mm
Aspect ratio	1.3068	1.3068
Active scan lines per frame	700	700
Frame time	42 s	42 s
Total line time	60 ms	60 ms
Active line time	56.82 ms	56.82 ms
Line retrace time	3.179 ms	3.176 ms
Black mask time (approx)	1 ms	1 ms
Active picture elements per line	832	832
Video carrier frequency	28.8 kHz	28.8 kHz
Video base band	7.35 kHz	7.35 kHz
Video sampling frequency	14.7 kHz	14.7 kHz
Video pass band	21.45 to 36.15 kHz	21.45 to 26.15 kHz
Bits/picture element	9	9
Lens cover	Transparent	None
Filters	Orange Green Blue Violet Minus blue 3 Polarizing: 0°, 60°, 120°	Minus blue
TV heater power (43.5 Vdc solar panel unregulated power)	6 W	18 W
TV power (50 V rms 2400 Hz square wave)	A + B = 33 W	
Camera head weight	5.05 kg	13.31 kg
Bus electronics weight	A + B = 7.74 kg	
Total weight (including bus electronics)	A + B = 26.10 kg	

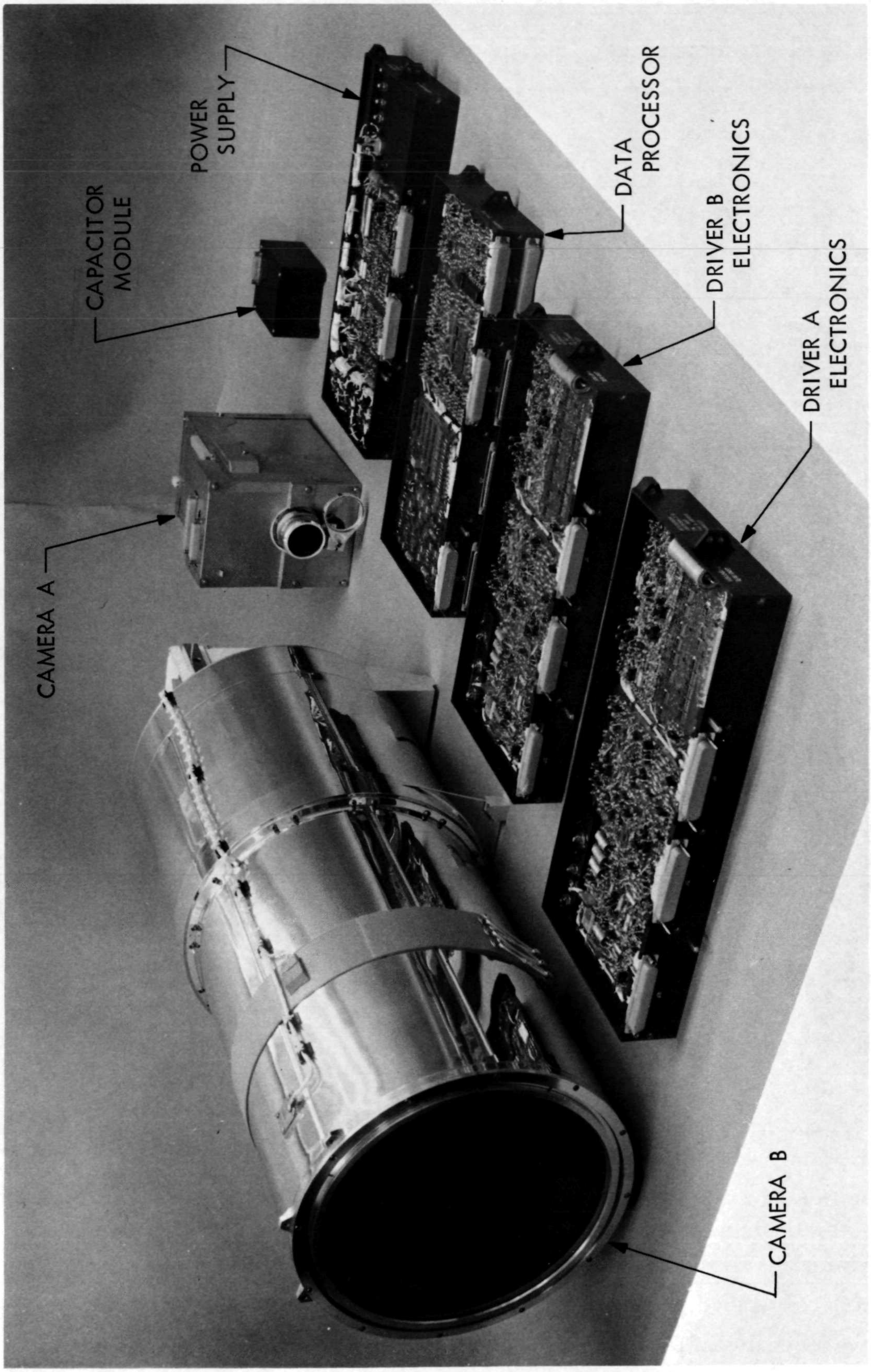

Fig. 1. Mariner Mars 1971 Television Instrument

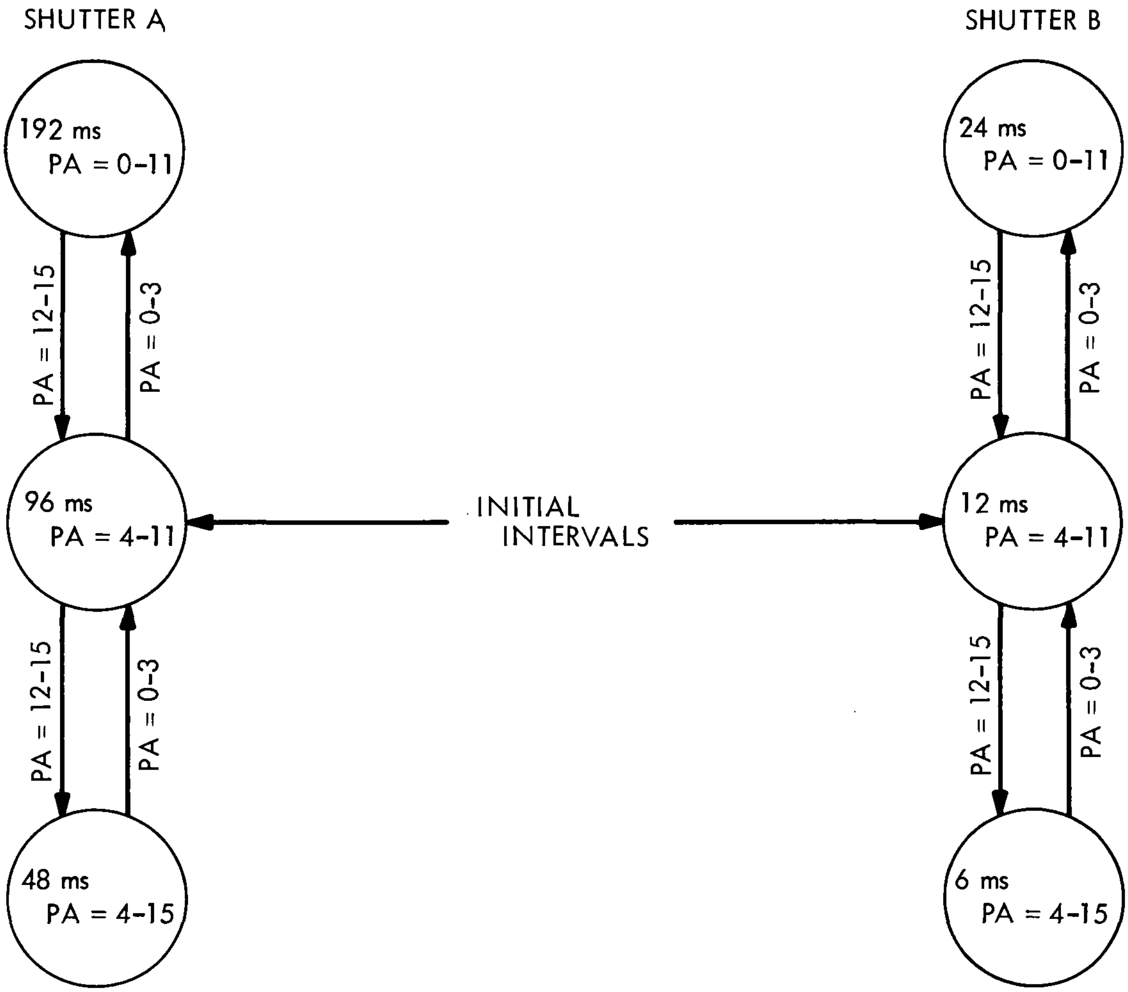

Fig. 2. TV shutter control via pixel averaging algorithm-state diagram

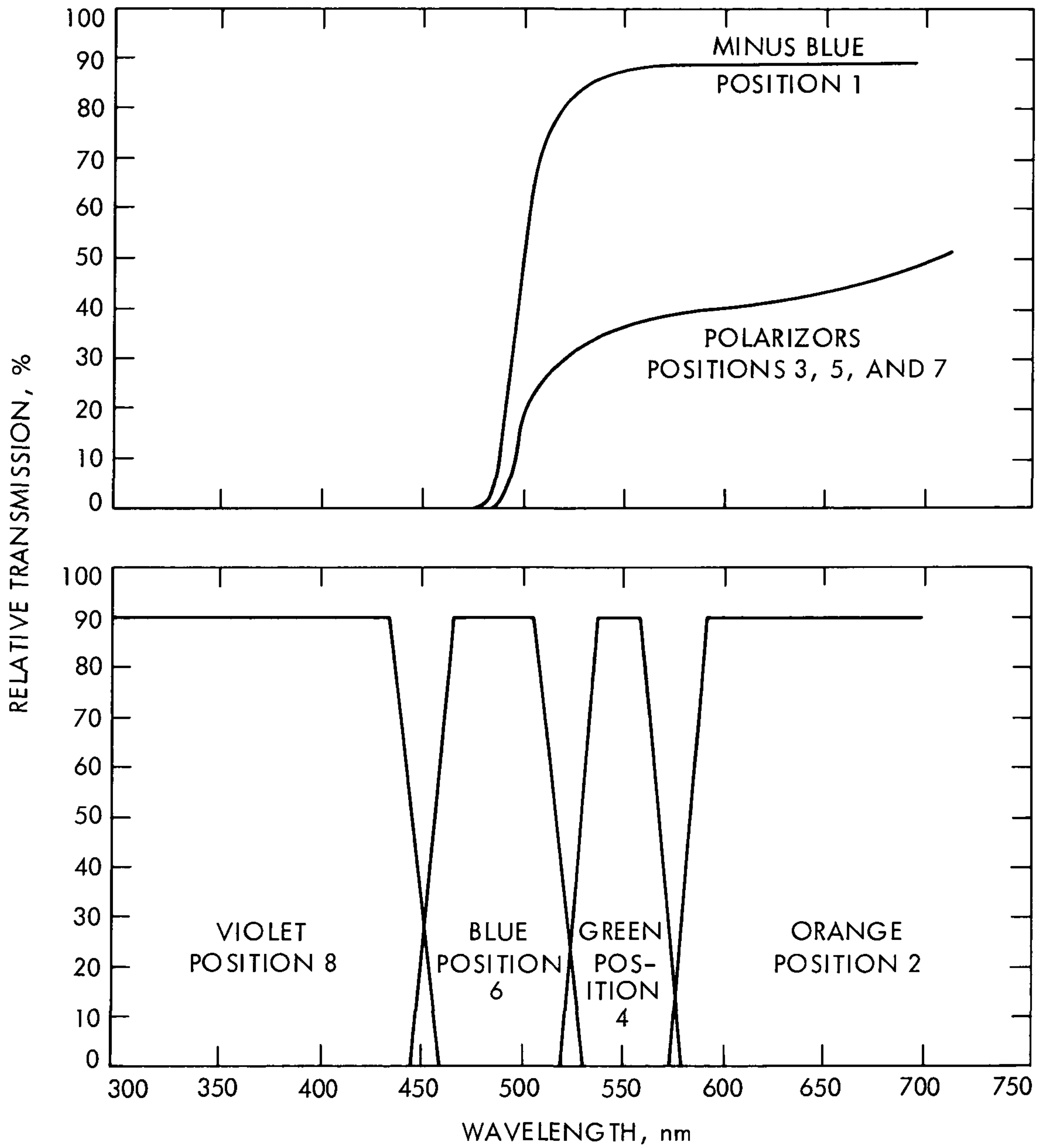

Fig. 3. Optical filter spectral response

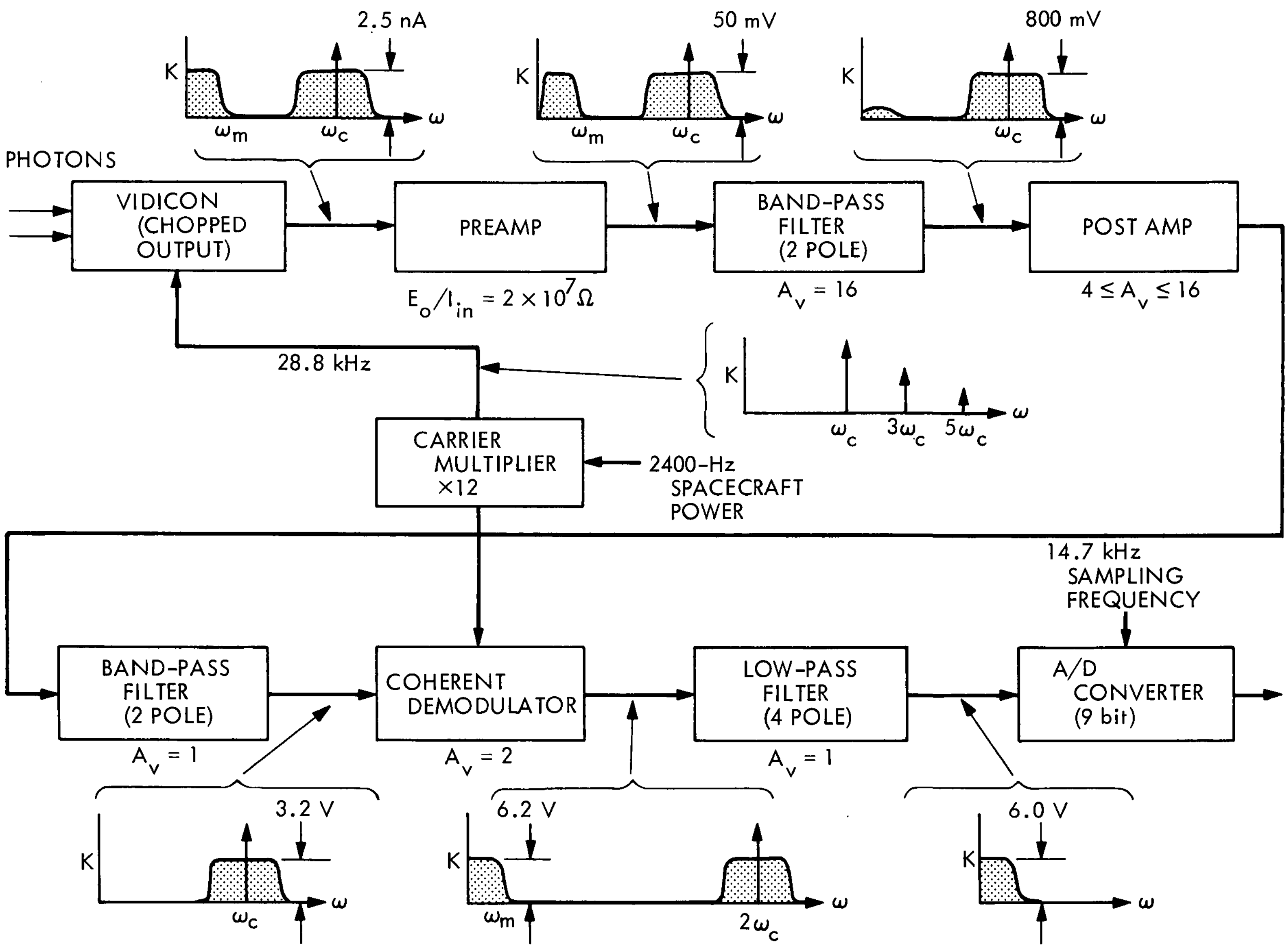

Fig. 4. Mariner Mars 1971 system video signal chain

NASA — JPL — Coml., L.A., Calif.